Damping in Nuclei[*]

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As the thermal excitation energy of a nucleus increases the level density becomes higher and the levels begin to mix. The energy range over which the levels mix is called the compound damping width, Γ_μ, and the properties of the levels within this range are damped, i.e. spread over all the levels. To study the onset of the damping process we need a nuclear property that varies rapidly over close-lying levels and rotational bands have such a property: the individual-particle spin alignments. Mixing such bands gives rise to a rotational damping width which can be measured following heavy-ion fusion reactions.

The relationship between rotational damping and compound damping is illustrated in Fig. 1. In this region the levels are mixed and a level (of spin, I) with three components ($\mu 1, \mu 2, \mu 3$) is shown on the right side of Fig. 1. Each of these components has different rotational properties and thus emits rotational γ rays having different energies. The level can then emit γ rays having any of these energies. This generates a distribution of γ-ray energies called the E2 strength distribution, whose width is called Γ_{rot}. This width depends only on the rotational properties of the admixed states. However, the wave function corresponding to each component will be spread over several levels at spin (I - 2), as well. This is illustrated on the left side of Fig. 1, where each component is schematically spread over three levels. The width of this distribution is Γ_μ. This width has essentially nothing to do with the rotational properties. It is apparent that it would be difficult to separate Γ_μ from Γ_{rot} in the full spectrum.

However, in a gated spectrum the gate will come in via one of the three components as illustrated in Fig. 1. The level can then decay via any of the components, but if it decays by the same (entry) component, it will have the sharp energy correlation characteristic of that rotational band, spread only by the distribution of the final states, Γ_μ. If it decays via either of the other two components, the width will be the full Γ_{rot}. Thus, if the components have equal amplitudes, one third of the events will have a width, Γ_μ, while two thirds have a width, Γ_{rot}. In the limit of only one component in the parent and daughter this results in just a single band, a very familiar situation. In the limit of many components, say 100, the probability of entering and leaving via the same component is small, 1%, and only Γ_{rot} will be seen. We have studied the intermediate situation where both widths have appreciable intensity.

The data for a mixture of $^{166,7,8}Yb$ nuclei were analyzed by comparing with simulated spectra generated by a program that followed the γ-ray decay in spin and excitation energy after a heavy-ion reaction. Although it is early in these studies, we believe that both Γ_{rot} and Γ_μ can be measured. This is because, in the way that each is populated in the spectra, they differ in width by a factor of about five, which is enough to make their effects resolvable. The Γ_{rot} values required to fit the data varied from 180 keV at 1.1 MeV γ-ray gate energy to 290 keV at 1.5 MeV and the uncertainties are about 20%. These values measure the spread (FWHM) in γ-ray energies emitted by a mixed state. For the compound-damped transitions, the *average* damping width, Γ_μ, ranged from 40 to 60 keV (FWHM) for the 1.1- to 1.3-MeV gates. We have not yet determined the uncertainties that should be associated with these Γ_μ values. These spreading widths are of general interest in nuclear physics and difficult to measure by other means in this excitation-energy range.
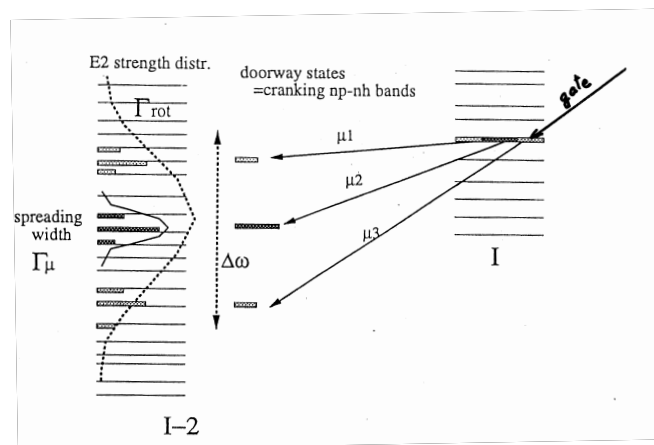

FIG. 1: An illustrative sketch of the mixed levels and transitions involved in rotational and compound damping. A gate is shown populating one component of a level of spin, I.